Half-life of ^{176}Lu

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The half-life of ^{176}Lu has been measured to be $(4.08 \pm 0.24) \times 10^{10}$ years.

[RADIOACTIVITY ^{176}Lu: Measured $T_{1/2}$. Ge(Li) detector.]

During the past forty years, the half-life of ^{176}Lu has been measured a number of times with widely scattered results. Published values for the half-life range from 2.1×10^{10} years[1] to 7.3×10^{10} years,[2] with the more recently reported values clustered in the range $(3.3-3.8) \times 10^{10}$ years.[3] Audouze *et al.*[4] suggested the use of ^{176}Lu as a means of determining the age of the *s*-process nuclei, and recently McCulloch *et al.*[5] have carried out such a study. The results obtained by use of this method depend upon the value taken for the ^{176}Lu half-life. Owing to the wide variation in the previously reported values, it was therefore felt that a new experiment should be performed to measure the ^{176}Lu half-life.

Previous decay studies have shown that ^{176}Lu β^- decays approximately 99.1% of the time to the 6^+ state at 597 keV in ^{176}Hf.[3] This decay is followed by a cascade of γ rays with energies of 306.9, 201.8, and 88.3 keV. There is also a weak (0.9%) β^- branch to the 8^+ level at 998 keV in ^{176}Hf. This decay produces, in addition to the previously mentioned γ rays, a 401.1 keV γ ray.[3] The present experiment consisted of measuring the yields of the 88.3, 201.8, and 306.9 keV γ rays during a specified counting interval from a known quantity of ^{176}Lu.

A 217-mg sample of 99.9% pure natural Lu metal (containing 2.61% ^{176}Lu)[6] in the form of a 0.127-mm thick foil was placed on the front of a well shielded 79-cm^3 coaxial Ge(Li) detector. γ-ray energy spectra were accumulated in 2048 channels with the use of a multichannel analyzer. The γ-ray spectrum observed during a 44.4 hour counting period is shown in Fig. 1. The Lu K x rays, 88.3, 201.8, and 306.9 keV γ rays are clearly seen along with a number of sum peaks. A very weak line is observed at 401.1 keV. Small unlabeled peaks are due to room background activities that were not completely removed by the shielding. The Lu sample was counted for a total of 77.2 hours; background measurements were performed for approximately 11 hours. Photopeak and total detector efficiencies were determined using accurately calibrated (3–5% uncertainties) standard γ-ray sources.

The background corrected yields of the 88.3, 201.8, and 306.9 keV γ rays were extracted from the data. Corrections were then made for summing effects, internal conversion, and attenuation in the sample. Using the tables of Rösel *et al.*,[7] the total (K) internal conversion coefficients for the 88.3, 201.8, and 306.9 keV transitions were calculated to be 5.87 (1.17), 0.281 (0.164), and 0.0751 (0.0519), respectively. These values for the total internal conversion coefficients were used to calculate the expected relative intensities of the three γ rays. The uncertainties associated with these internal conversion coefficients are estimated to be approximately 10%, 5%, and 2% for the 88.3, 201.8, and 306.9 keV γ rays, respectively. The attenuations of the γ rays in the sample were calculated with the use of the photon cross section tables of Storm and Israel.[8] Assuming that the ^{176}Lu is uniformly

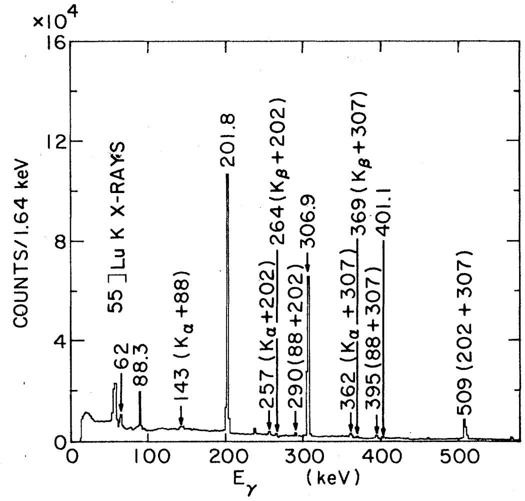

FIG. 1. γ-ray spectrum observed during a 44.4 hour counting period from the Lu sample. The Lu K x rays, 88.3, 201.8, and 306.9 keV γ rays from the decay of ^{176}Lu are clearly seen along with a number of peaks due to γ-γ or γ-x summing. A very weak line is observed at 401.1 keV. Small unlabeled peaks are due to room background.

TABLE I. Results of the present and previous experiments for the half-life of ^{176}Lu.

Author	$t_{1/2}$(10^{10} years)
Heyden and Wefelmeier, Ref. 9	4
Libby, Ref. 2	7.3 ± 2
Arnold, Ref. 10	2.15 ± 0.10
Dixon *et al.*, Ref. 11	4.56 ± 0.3
Glover and Watt, Ref. 1	2.1 ± 0.2
Herr and Merz, Ref. 12	2.17 ± 0.35
McNair, Ref. 13	3.6 ± 0.1
Donhoffer, Ref. 14	2.18 ± 0.06
Brinkman *et al.*, Ref. 15	3.6 ± 0.1
Sakamoto, Ref. 16	5.0 ± 0.3
Prodi *et al.*, Ref. 17	3.27 ± 0.05
Komura *et al.*, Ref. 18	3.79 ± 0.03
Present work	4.08 ± 0.24

distributed throughout the foil, the transmissions of the 88.3, 201.8, and 306.9 keV γ rays were found to be 0.548 ± 0.055, 0.930 ± 0.074, and 0.971 ± 0.049, respectively. The uncertainties in the transmissions reflect the uncertainties in the photon cross sections and those associated with the experimental geometry.

The final results obtained for the half-life of ^{176}Lu may be summarized as follows: the half-lives of the 88.3, 201.8, and 306.9 keV γ rays were determined to be, in units of 10^{10} years, 3.47 ± 0.52, 4.16 ± 0.42, and 4.28 ± 0.34, respectively. The weighted mean value for the half-life of ^{176}Lu, as determined from the present experiment, is $(4.08\pm0.24)\times10^{10}$ years. Table I shows a comparison of the present result with previously reported values for the half-life of ^{176}Lu.

Despite the considerable care taken in the present study, the value obtained for the ^{176}Lu half-life has a considerably larger uncertainty than those of several of the previously reported values. The major sources of uncertainty in the present experiment are the uncertainties in the corrections for sample attenuation, uncertainties in the internal conversion coefficients, and uncertainties in the strengths of the γ-ray standards that were used to measure the detector efficiency. However, the present result is sufficiently precise to allow the use of ^{176}Lu as a cosmochronometer and implies that the half-life of ^{176}Lu lies closer to the more recently reported values[3] than to either extreme of the earlier reported values.[1,2]

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